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Combined results of searches for second generation leptoquarks

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Abstract

We report on the combination of the searches for second generation scalar leptoquarks performed using 198 pb^{-1} of Run II data.
We combine the results of the searches in three channels: $\nu\nu jj$[1] , $\mu\nu jj$[2] and $\mu\mu jj$[] are combined obtaining an upper limit on the production cross section as a function of the leptoquark mass and the branching ratio β= Br(LQ eq). By comparison with the theoretical expectations[4] we set lower limits on m(LQ) as a function of β.

Introduction

Searches for pair produced second generation LQ have been performed using Run II data in three channels:

- $\mu\mu jj$ – This search gives an upper optimal limit for branching ratio β= Br(LQ eq). = 1. The limit obtained with 198pb^{-1} is m(LQ) > 221 GeV/c^2 at 95% CL;
- $\mu\mu jj$ – This search gives the highest optimal limit for a branching ratio β= Br(LQ eq). = 0.5. The limit obtained with 198pb^{-1} is m(LQ) > 170 GeV/c^2 at 95% CL).
- $\nu\nu jj$ – The optimal limit is obtained for β= Br(LQ eq). = 0.0 and the CDF results, based on 191pb^{-1} is m(LQ) > 117 GeV/c^2 at 95% CL .

In Figure 1 we present the exclusion regions as function of β obtained from the single channel analysis ββjj and ββjj.

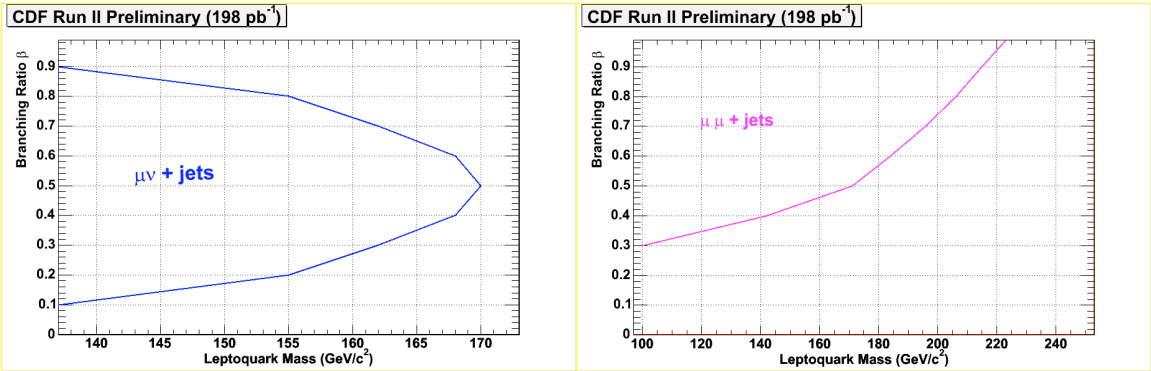

Figure 1 – Exclusion regions as a function of Br(LQ eq) obtained from the single ββjj and ββjj channels. The areas at the left of the curves are excluded at 95% CL.

In figure 2 the exclusion region from the ββjj analysis is reported. We can see that the limit is really relevant for values of β < 0.09.

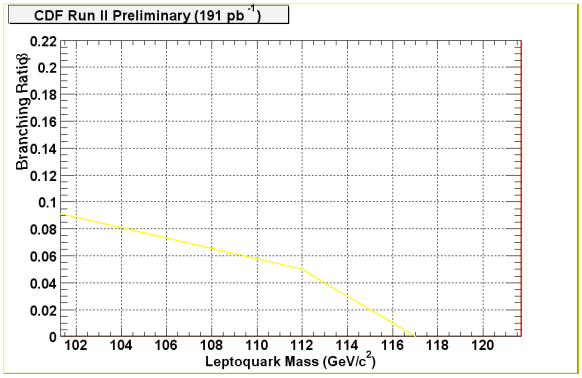

Figure 2 - – Exclusion regions as a function of Br(LQ eq) obtained from the single ββjj. The areas at the left of the curves are excluded at 95% CL.

The individual channels results are combined using a procedure based on a Bayesian approach[5], which takes into account the correlations in the systematic uncertainties.

Method

To calculate the limits combining all the available leptoquarks decay channels we have used a Bayesian approach. A joint likelihood has been formed from the product of the individual channels likelihood. For each mass we simulated 10K pseudo-experiments,

smearing the calculated number of background events and the estimated number of signal events by their respective total uncertainties. The searches in the □□jj and □□jj channel use common criteria and sometime apply the same kind of requirements (for example on the tight electron identification) so the uncertainties in the acceptances have been considered completely correlated (which gives the most conservative limit). When calculating the limit combination including also the □□jj channel the uncertainties in the acceptances have been considered uncorrelated.
We want to spend a few words on the technical aspects of the modified bayes[5] program which has been used in the calculation of the combined limit. The program uses a likelihood-based limit procedure and produces a joint likelihood where the likelihood for each channel is multiplied together. At the end one variable for the signal, Nsig, is obtained. To get the limit cross section for channel *i*, one uses the formula:

$$\sigma_{LIM} = N_{LIM}/(\varepsilon \cdot \mathcal{L})$$

where ε is the efficiency for the channel in consideration. For more than one channel we use the formula:

$$\sigma_{LIM} = N_{LIM}/(\varepsilon_{average} \cdot \mathcal{L})$$

where $\varepsilon_{average} = (\beta^2 \cdot \varepsilon(\square\square jj) + 2\beta(1-\beta)\cdot\varepsilon(\square\square jj) + \beta^2 \cdot \varepsilon(\square\square jj \text{ as } \square\square jj))$ for the 2 channels case and $\varepsilon_{average} = (\beta^2 \cdot \varepsilon(\square\square jj) + 2\beta(1-\beta)\cdot\varepsilon(\square\square jj) + (1-\beta)^2 \cdot \varepsilon(\square\square jj) + \beta^2 \cdot \varepsilon(\square\square jj \text{ as } \square\square jj)))$ for the three channels case.

For each β value a limit on the expected number of events is returned for each mass. The resulting cross section limit is then compared with the theoretical production cross section for the 2 channels case and for the 3 channels case (figure 3). In deriving the mass limit we consider the total production cross-section, as the branching ratio is already counted in the average efficiency formula.

Results

The results of the combination for second generation scalar leptoquarks are presented in Figure 3, using the information coming for all three decay channels: □□jj, □□jj,□□jj combination

In Figure 3 we report the exclusion region in the plane defined by the branching ratio β and the LQ mass. The mass limits are obtained by comparing the cross section 95% CL limit with the theoretical prediction β branching ratio as function of the leptoquark mass for different values of β. At the intersection point the mass limit is derived.

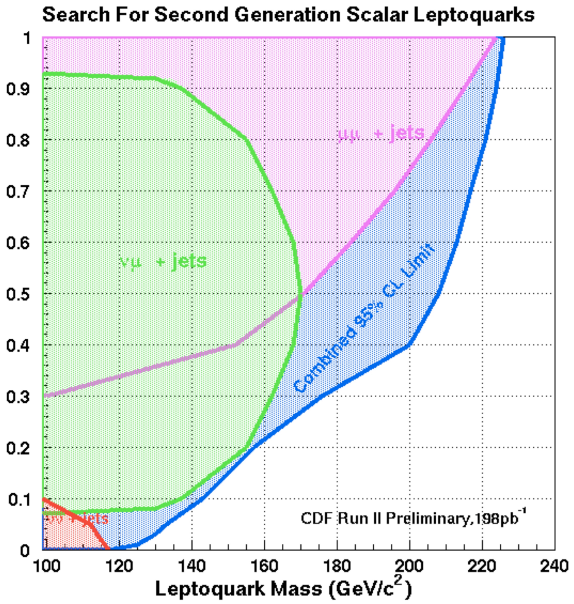

Figure 5 – – Exclusion regions as a function of Br(LQ eq) obtained from the single jj and jj and jj channels, and their combination (blue curve). The areas at the left of the curves are excluded at 95%CL.

In Table 1 we report the combined 95% CL cross section limits for different LQ masses and for some values of . The combination is performed also for = 1, since the jj analysis has a non-zero efficiency for di-muons events, when one of the muons is misidentified (see also the definition of the average efficiency).

M(LQ) GeV/c^2	=0.2	=05	=1.0
	$_{95}$ (pb)	$_{95}$ (pb)	$_{95}$ (pb)
100	7.8	3.9	1.3
120	1.3	0.5	0.3
160	1.0	0.4	0.14
200	0.4	0.23	0.11
220	0.36	0.17	0.10
240	0.4	0.20	0.09

Table 1 – 95% CL combined cross section limits for different values of , obtained from the combination of eejj and ejj channels

In Table 2 we report the 95% CL upper limit on the leptoquark mass in the case where only 2 channels are combined or the three are combined. The limits are the same for $\beta \geq 0.1$, while for small values of β the inclusion of the third channel improves in the low β region.

β	Mass 95% Upper Limit(GeV/c^2) 3 channels	Mass 95% Upper Limit(GeV/c^2) 2 channels
0.01	125	NaN
0.03	130	NaN
0.05	133	123
0.07	137	130
0.1	143	143
0.2	157	160
0.3	176	176
0.5	208	210
0.9	224	224
1.0	226	226

Table 2 – 95%CL mass upper limits for the combination of three channels and two channels.

Conclusions

We have performed the combination of all the CDF searches for second-generation scalar letpoquarks using Run II data. The results are combined using a procedure based on a Bayesian approach, which takes into account the correlations in the systematic uncertainties.
We set 95% CL lower limit for scalar second generation leptoquarks at 143 GeV/c^2 (β =0.1), 208 GeV/c^2 (β =0.5) and 226 GeV/c^2 (β =1.0).

Acknowledgements

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References

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2) Search for second generation leptoquarks pair production in e□jj, S. Rolli, D.Ryan and H. Sun ,CDF/ANAL/EXOTIC/CDFR/7016, August 2004
3) Search for Second-Generation Leptoquarks in the Jets and Missing Transverse Energy Topology. D. Acosta, K. Konigsberg, A. Moorhead, D. Tsybychev, S.M. Wang. CDF/ANAL/EXOTIC/PUBLIC/7169
4) Pair Production of scalar LeptoQuarks at the TeVatron, M. Kramer et al., Phys Rev Lett 79, 341, 1997.
5) Combined Results of Searches for Second Generation Leptoquarks, Lorenzo Moneta. CDF/ANAL/EXOTIC/PUBLIC/5790

Appendix A: Comparison between 1st and 2nd generation combined limits

In Figure A1 we report the combined limits as function of □ for 1st and 2nd generation scalar leptoquarks.

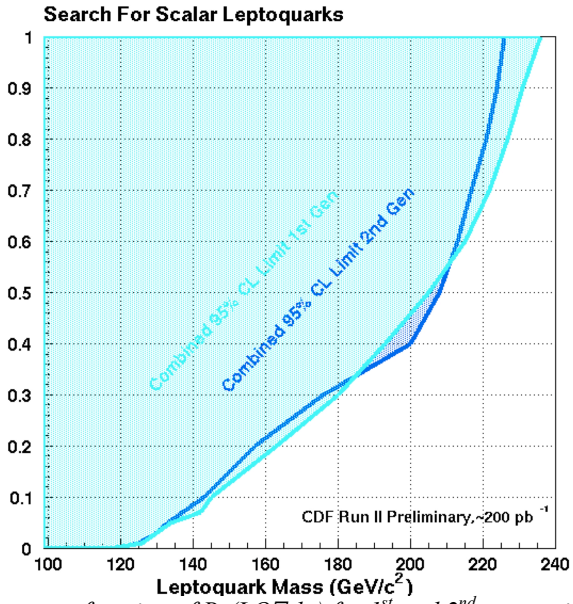

Figure A1 -– Exclusion regions as a function of Br(LQ□ lq) for 1st and 2nd generation LQ. The areas at the left of the curves are excluded at 95%CL.